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By
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# Psychological Monographs:
## General and Applied

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HERBERT S. CONRAD, *Editor*

# Effects of Exposure to Sound on Discrimination Performance in the Rat

*By*

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Jane Shohl

## I. PURPOSE AND METHOD

Since Maier's work (1) first attracted widespread attention to the phenomenon which he described as "neurosis in rats," the door has been opened to controversies concerning the exact nature and basis of the responses he studied. Most attention has been paid, however, to variables affecting the neurotic pattern, and almost none to the relationship of this type of behavior to other behavioral functions. Although numerous studies of learning and discrimination performance have been made with rats, and many reports of abnormal behavior in rats are now at hand, only a few have been concerned with the relationship of learning to abnormal behavior. The experiment to be reported presents data on discrimination learning in relation to abnormal behavior in rats.

The experiment to be described is a study of: (*a*) the relationship of learning ability and susceptibility to sound-induced seizures in the rat; and (*b*) the effects of exposure to noise on the performance of rats in a difficult discrimination situation.

The general plan of the experiment required that rats be practiced on a discrimination problem. Then they were subjected to auditory stimulation, which produced convulsions in certain rats. Finally, they were studied as to discrimination performance for changes in error scores, time scores, and qualitative behavior following the exposures.

Fifty albino rats, 27 females and 23 males, finished the experiment. They were taken from the stock of the University of Michigan Psychological Laboratory, and they were not selected in any way except for age. Preliminary training was begun when the animals were approximately 4½ months old. They were somewhat more than 7½ months old when first exposed to sound stimulation. None of the animals had previously been used for experimental purposes.

The animals were fed throughout the experiment on the stock laboratory diet. The animals were housed in standard laboratory cages, segregated for sex. The living cages were located in the same room as the apparatus used, but were in a different room from the sound-testing apparatus.

The plan of the apparatus is shown in the accompanying diagram. It was designed to reproduce the setup originally described by Maier:

> "In general the experimental situation may be described as follows: Three tables are placed side by side with their near points 30 cm. apart. From the central table an elevated pathway (made from strips of wood ¾" x ¾" in cross section) is built. This pathway branches into two symmetrical parts, one arm leading to the table on the left, the other leading to the table on the right. The right (R) and left (L) tables are different in size and shape and so have decided differences in character. . . .
>
> "The rats were trained to go to a stimulus light (electric lamp wrapped in brown paper) for food. Since the rat was placed at a central point on the middle table and the food and stimulus-light on the nearest corner of either the right or left table, the rat, if it is to get consistently to the food without error (going to the table without the stimulus light) has to react to the stimulus light" (2, p. 289).

The pathway pattern used in the present experiment most closely resembles Maier's pattern (*d*). The size, shape, and surface of the two goal-tables are purposely made as different as possible in order to aid the animal in orienting itself to the situation. The pattern was not altered during this experiment.

The stimulus light used in the present experiment was an electric bulb mounted on a movable frame and enclosed in ground-glass panes. The frame also carried a foodbox containing the reward, so that cue and goal were one structural unit.

In operation, one animal was placed on the starting table, allowed to look at the light-cue, and permitted to run the pathway to the food-goal. At the choice-point, the animal was penalized for an incorrect turn by increase in the time and distance of travel needed to reach the goal-table. It is evident that while the basic problem is a visual discrimination, there are certain elements of a delayed reaction problem, of maze-running, and, possibly, of reasoning in-

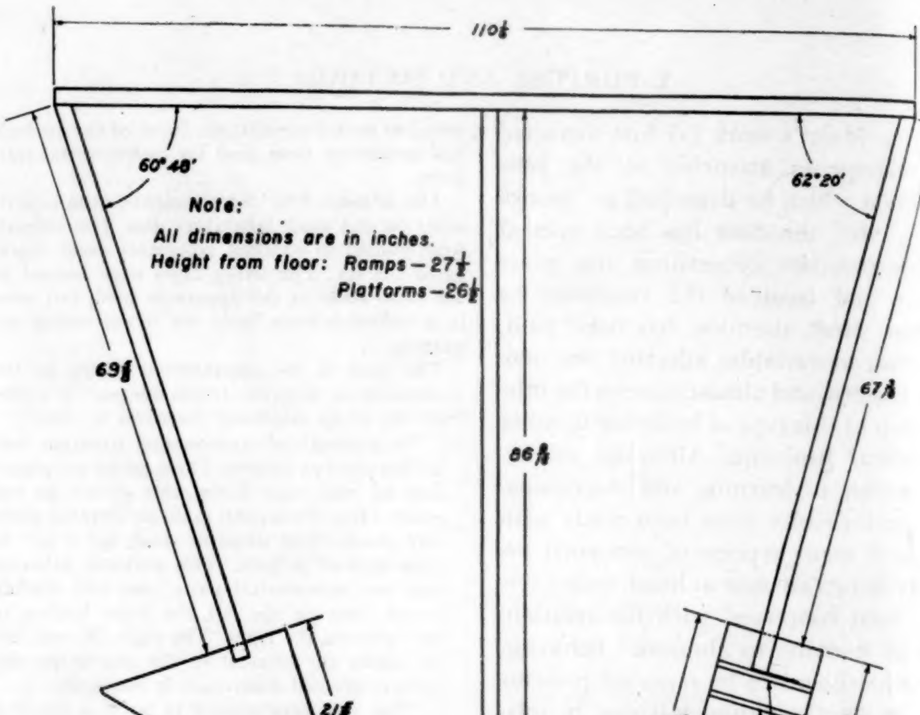



FIG. 1. PLAN OF APPARATUS

volved in making a successful solution.

The animals did not receive enough food during the day's trials to maintain health; so on completing the daily schedule, they were placed in groups on a feeding stand and allowed to finish the day's ration.

Twenty-four-hour hunger motivation was used throughout the experiment. The amount of food was controlled in such a way as to obtain prompt running activity while maintaining the animals at approximately constant weight and in apparent good health, and was varied slightly from time to time during the experiment to meet these requirements.

The rats were given a preliminary training period of several stages before being run on the apparatus described. The purpose of the training was to establish an association between the location of the light and the location of the food. This training was identical for all animals. The preliminary training program covered a period of approximately ten weeks.

The procedure for running was the same for all animals and was constant throughout the experiment. All animals completed ten trips on the pathway each day. The 50 animals made a total of 500 trips each day on the pathway.

It should be especially noted that:

1. The animals were allowed to correct their own errors. No animal was considered to have completed a trip on the pathway until it had reached the food-box.

2. The animals were tossed to the starting table from a distance of about two feet to prevent the experimenter from orienting the rat inadvertently to the right or left.

3. The position of the goal light was changed during each day's runs according to a predetermined "chance" order. A given order was repeated every fourth day. The same order series was used throughout the experiment. There was no evidence that the rats learned it. Thus, the rat could not succeed by maintaining stereotyped spatial responses but was obliged at every trial to face a repetition of the problem as to which path was correct and to solve it in terms of the location of the cue. In this respect, the setup differs from an ordinary maze-running problem, where standardization of certain spatial responses is the essential requirement. Once an animal has consistently achieved an error score less than that to be expected by chance in the present problem, it may be said to have "learned" to obtain food, but promptness and accuracy of performance may continue to vary as a result of other factors, e.g., motivation, alertness, fatigue, etc. The animals were considered to have "learned" this problem after 20 consecutive errorless trials (10 on each of two consecutive days).

4. The animals were run in the afternoon and evening as much as possible to minimize distractions from incidental laboratory noise and to reduce general illumination.

5. The individual rats were always run in the same order so that the interval between feedings was approximately constant for every animal in the group. As the animals varied in their speed of running with training, the time of running for any given animal varied somewhat from day to day during the course of the several months over which the experiment lasted.

6. Vacations of up to three days were given (to all animals at the same time) at irregular intervals throughout the experiment, because it had been originally intended that the effect of such vacations would be studied.

7. The pathway was located in a different room from the soundbox used for making auditory exposure.

In order that the effect of exposure to sound and of sound-induced convulsions on discrimination performance could be studied, animals were subjected to the following procedure:

Exposures to sound, intended to produce convulsions, were carried out by placing the animals in groups of four in the sound chamber described and exposing them to the sound of jingling keys for a period of one minute. The animals were exposed to the noise of jingling keys in a specially enclosed soundproof box. The keys were mounted on a motor-driven arm. The top of the box was transparent to provide visibility. The box has been described (3). *One hour* after exposure on the test days, the animals were run on the discrimination problem in the same way as described for the preceding part of the experiment.

The division into experimental groups was made so as to equate the groups as nearly as possible for litter, sex, and discrimination error score for the ten days just preceding the first exposures.

The sound exposures were begun on the sixty-second experimental day and finished on the ninety-eighth experimental day. The experimental design is given in summary form:

SCHEDULE OF EXPERIMENT

| | Group A | Group B | Group C |
|---|---|---|---|
| Preliminary Training | | | |
| Discrimination Practice | | | |
| Test Period I | Sound Exposure | Sound Exposure | Control |
| Test Period II | Control | Control | Sound Exposure |
| Test Period III | Sound Exposure | Sound Exposure | Control |
| Test Period IV | Control | Control | Sound Exposure* |

The records of errors, time, qualitative behavior, and convulsive pattern were made for each animal. Inasmuch as almost all the records were taken by a single observer, the element of personal error is, so far as known, consistent throughout the experiment.

## II. RESULTS

### A. Relation Between Learning and Susceptibility to Convulsions

Because extensive data are available for the discrimination practice period and for the exposure tests to sound, it is possible to study the relationship between discrimination performance and susceptibility to convulsions.

Auditory testing began on the sixty-second experimental day. By this time, only 18 of the animals had satisfied the learning criterion of two consecutive errorless days. Therefore, the relation of learning ability to convulsions was studied in two ways: (*a*) regarding the learners as a special group; and (*b*) for the entire group of animals.

#### *1. Incidence and Frequency of Convulsions in Learners*

*Incidence.* Of the 18 animals which had met the learning criterion before the sound tests began, 9 animals had convulsions during the subsequent test periods whereas 9 animals had none. Judged by this comparison, there is no relation whatsoever between learning ability and susceptibility to convulsions.

*Frequency.* The 9 animals which learned and also had convulsions had, as a group, a total of 39 convulsions. These 9 animals represent approximately one-third of the total number of animals having convulsions (26), and 39 represent approximately one-third of the total number of convulsions which occurred (113). Actually, convulsers which learned averaged 4.3 convulsions; nonlearners averaged 4.4 convulsions. This indicates that the learners do not differ from the nonlearners materially with respect to the frequency of convulsions in animals which have them.

*Learning order.* Of the first 5 animals to learn, 21M, which made by far the best learning record of any rat in the group, had *no* convulsions; the second rat to learn had *ten* convulsions. Of 2 rats tied for third in rate of learning, 1 had nine convulsions whereas the other had none. The rats which were fourth and fifth in rate of learning had no convulsions. There is certainly no evidence here that learning ability is related to susceptibility to convulsions.

*Time required for learners to meet criterion.* The average number of days required for the convulsers to meet the criterion was 48.6, whereas the average for the non-convulsers was 45. In view of the wide range in rate of learning (day 10 to day 96) this slight difference (3.6 days) in favor of the non-convulsers is probably negligible. If the one phenomenal learner of the experiment is omitted from the non-convulsing group, the difference is even less.

#### *2. Learning in Convulsers Contrasted with Non-convulsers*

Although the above comparisons have been restricted to animals which learned before sound tests began, additional comparisons of learning scores can be made for the entire group of 50 animals divided with respect to occurrence vs. nonoccurence of convulsions.

*a) Errors for entire pretest period.* The group of animals which convulsed averaged 87.1 errors for the period, or a mean of 3.3 errors per day. The group of animals which at no time convulsed

averaged 79.7 errors for the period, or a mean of 3.3 errors per day. No difference is found, i.e., convulsers do not differ from non-convulsers in discrimination performance.

*b) Errors for ten-day period immediately preceding tests.* To make sure that no differences are obscured by differences in rate of learning, in spite of data available which cast considerable doubt on the existence of such a difference, the error status of convulsers and non-convulsers for the ten-day period just prior to the beginning of tests has also been examined. The mean number of errors per day for the group which convulsed is 2.3; the mean number of errors per day for the non-convulsers is 2.4. Again, there is no evidence that convulsers differ from non-convulsers with respect to learning achievement.

*c) Time required for learners to reach criterion.* Of the group of 26 convulsers, 8 failed to meet the criterion of learning by the close of the experiment. Of the group of 24 non-convulsers, 5 failed to meet the criterion of learning by the close of the experiment. For the remaining 18 convulsers which learned at some time or other during the course of the experiment, the mean number of days required to reach the criterion was 65.2. For the remaining 19 non-convulsers which learned at some time or other during the experiment, the mean number of days required to meet the criterion was 66.3. Particularly in view of the wide range in number of days required to meet the criterion by the different rats (days 10–96), this difference (1.2 days) is negligible and supports the impression gained from examining the error scores that there is no obvious relation between discrimination performance and susceptibility to convulsions.

### B. Effect of Auditory Stimulation on Discrimination Performance

One of the major objectives of the experiment was to find out how exposure to sound affected performance in a long-practiced discrimination. It was particularly desired to study the effects where animals showed signs of abnormal behavior during the exposure to sound. The following sections give the results of the analysis.

#### *1. Pretesting Performance Compared with Performance for the Entire Experiment*

To obtain a crude indication as to gross effects of the sound tests, performance before the beginning of tests was compared with performance for the entire experiment in terms of errors, starting time, and total time. Pearson product-moment coefficients of correlation have been calculated and are presented in Table 1. The high correlations between the data for the pretest and total periods (.91 for errors, .85 for starting time, .94 for total time) show that there is no gross effect of the sound-testing which can be detected by this means.

TABLE 1

Intercorrelations: Pretest Scores vs. Total Scores

| | Total Errors | Total Starting Time | Total Total Time |
|---|---|---|---|
| Pretest errors | .91 | — | — |
| Pretest starting time | | .85 | — |
| Pretest total time | | | .94 |

#### *2. Effect of Exposure Alone on Discrimination Performance*

The plan of the experiment included evaluation of the effects of exposure to sound on the discrimination performance of the animals. The test exposures were

made as described in the section on procedure. First, attention will be paid to the effects of exposure alone.

In this paper, the term "seizure" is a general epithet including any and all abnormal behavior patterns elicited by exposure to sound. The term "convulsion" is restricted to patterns where the animal showed unmistakable, severe in-co-ordinated alternating contraction and relaxation of body muscles. "Convulsion" as used in this discussion does *not* include cases where the violent running pattern described by others, and also observed in these animals, occurred alone. When, as frequently happened, the animal exhibited the violent running pattern and immediately went on to have a convulsion, the animal was credited with a "convulsion" during the exposure in question.

*(a) Performance on exposure days compared with performance on control days.* Performance on control days was compared directly with performance on exposure days for each rat. In making this comparison, "control days" were considered as being all days after the start of auditory testing on which the individual animal was not exposed to sound. They, therefore, differed in calendar date for the different animals, and included days intervening between tests as well as days of the control periods proper. "Exposure days" were taken to include all days on which the individual was exposed to sound *except* those days on which the animal, if a convulser, had a convulsion. Individual means were prepared for each animal for the control days and for the exposure days and these means were treated to obtain mean scores for the group for control days and for exposure days.

The results of comparing performance on control days and on exposure days in terms of errors are given in Table 2. The mean daily error score was 1.7 for control days, when not exposed, and 1.8 for days when the same animals were exposed but did not have a convulsion. This difference, for those animals which can be compared (i.e., all but the two which had ten convulsions), is not reliable by the *t*-test (4). The results indicate that exposure to sound does not produce a significant increase in errors in running

TABLE 2
EFFECT OF EXPOSURE TO SOUND ON ERRORS IN DISCRIMINATION

| | Average Errors | |
|---|---|---|
| | Control Days | Exposure Days |
| Total | 84.9 | 88.2 |
| Mean | 1.7 | 1.8 |
| Difference | | 0.1 |

The results of comparing performance on control days and on exposure days in terms of starting time are given in Table 3. The mean daily time score was 28.8 seconds on control days, when not exposed, and 36.1 seconds on exposure days, when the same animals were tested to sound but had no convulsion. This difference, for those animals which can be compared, is not reliable by the *t*-test. There is no significant tendency for rats to express disturbance, following tests to sound, by an increase in starting time.

*(b) Relation of exposures to position habits.* In the jumping stand, and in the discrimination problem used in this experiment, position habits take the form of consistent choices to the right or left on

TABLE 3
EFFECT OF EXPOSURE TO SOUND ON STARTING TIME IN DISCRIMINATION

| | Average Starting Time | |
|---|---|---|
| | Control Days | Exposure Days |
| Total | 1438.2 | 1732.2 |
| Mean | 28.8 | 36.1 |
| Difference | | 7.3 |

every trial, whatever the position of the goal might be. In this experiment, the position of the goal was shifted in a "chance" order so designed that the goal was placed to the right for one half of each day's trials, and to the left for the other half. A rat having a position habit necessarily makes five correct and five incorrect choices each day under these conditions, i.e., is credited with a chance error score although it is not responding in random fashion.

The behavior represents a partial solution to the rat's problem, "Which way shall I go to get food?" since it tells the rat which way to go, but falls short of the optimal solution in terms of the goal inasmuch as the rat does not gain access to the food promptly. The position habit is, therefore, a relatively inadequate form of behavior. Here it is of interest to see whether such inadequate and stereotyped behavior occurred more frequently after exposure to sound.

In making the analysis, a rat was considered to have a position habit for the day if *all* his choices for that day were to the same side. The incidence and direction of position habits for each individual rat were assembled with the experimental day number when they occurred. Day numbers when position habits occurred were matched with day numbers when the animals were exposed to sound.

The records showed that 42 of the 50 rats had position habits at some time or other during the course of the experiment. Of the 8 animals which failed to have them, 3 were convulsers and 5 were non-convulsers. Of the remaining 42 animals, 24 showed position habits which were entirely confined to the period before auditory testing began, and these animals could, of course, show no relationship between position habits and exposures.

When the records of the remaining 18 animals were examined, a most interesting fact emerged: all but two of the 18 rats which had position habits during the exposure periods were convulsers. Since only about half the animals in the experiment were convulsers, the position habit group contains an extremely heavy proportion of convulsers. This became even more significant when the records of the two non-convulsers who showed position habits during the testing period were closely inspected. Both of these animals developed position habits early in the experiment, and maintained them for long periods prior to the beginning of the tests. Consequently, continuation of the position habits throughout the testing period seems to demonstrate for these animals merely the persistence of a pattern developed long before the exposures to sound. The records of the 16 convulsers with respect to position habits will be discussed in detail elsewhere, when the effects of convulsions on performance are considered. From the survey already made, it seems clear that in non-convulsers exposure to noise of itself has no tendency to promote the occurrence of position habits even in animals which had previously shown them, and certainly did not cause them to appear *de novo* in animals which had never shown them before the beginning of sound tests.

*(c) Relation of exposures to qualitative disturbance.* In observing the daily behavior of the animals, special note was made of apparent disturbance in their customary manner of running. The usual run was immediate, direct, and rapid, without hesitation or delay of any kind. Disturbances observed during the course of the experiment took serveral forms.

1. The rat might remain motionless on the starting table—unnaturally quiet for a rat—without exploration or head movement after the manner of rats exposed to an entirely new situation.
2. The rat might run the pathway, but in a jerky manner, with his belly to the pathway.
3. The rat might hesitate markedly, or balk at the corners of the pathway.
4. The rat might appear particularly sensitive to slight incidental noises.
5. The rat might show unusual responses at certain points in the pathway, e.g., refuse to approach the food contained after reaching the goal-table, or refuse to step onto the goal-table from the pathway.
6. The rat might retrace part or all of the distance traveled.
7. The rat might defecate on the apparatus.
8. The rat might wash its face at the choice-point and corners.
9. The rat might, in this very familiar situation, sniff at the pathway.

Patterns 5, 6, 7, 8, and 9 occurred rarely, usually were characteristic of one or two animals, but were almost never observed during the long period of running before the beginning of the sound tests. All the patterns described were arbitrarily called "x" patterns, and were taken to show qualitative behavior disturbance. Runs on which such behavior appeared were designated "x-runs."

Individual animals were compared with respect to the average number of runs each day on which the rat displayed some form of qualitative disturbance in behavior. The behavior had been noted in 27 animals at some time or other on days when they were not exposed, and in 10 animals at some time or other on days when they were exposed but had no attacks. The number of times the behavior appeared was, however, increased on the exposure days (from an average of 0.8 to 2.3) for animals which showed it, and appeared in certain animals with considerable frequency. Evidently, a few of the rats expressed disturbances following exposure to sound by changes in the qualitative features of the running behavior, but this was a highly individual matter.

### *3. Effect of Convulsions on Discrimination Performance*

*(a) Performance on convulsion days compared with performance on control days.* Performance on control days was compared for each animal directly with performance on days when the rat had a convulsion. Control days were the same days considered as in making the corresponding comparisons for the effects of exposure only. Convulsion days were all those days on which the animal in question showed a complete convulsive pattern on exposure to sound. Individual means for each animal for control days and convulsion days were obtained, and these means treated to obtain mean scores for control days and for exposure days.

The results obtained by comparing errors in performance on control days with errors on convulsion days are presented in Table 4. Although exposure of itself has, as previously shown, little or no effect in producing increase in errors in running, convulsion has a decided effect in increasing errors in running.

TABLE 4

EFFECT OF CONVULSIONS ON ERRORS IN DISCRIMINATION PERFORMANCE

| | Average Errors | |
|---|---|---|
| | Control Days | Convulsion Days |
| Total | 84.9 | 68.1 |
| Mean | 1.7 | 2.6 |
| Difference | | 0.9* |

* Significant at less than 1% level.

The results obtained by comparing starting time on control days with starting time on convulsion days are presented in Table 5. There is a decided

tendency for a rat which had previously had a convulsion to show an increased starting time on its trials for the day.

TABLE 5

EFFECT OF CONVULSIONS ON DISCRIMINATION PERFORMANCE

| | Average Starting Time | |
|---|---|---|
| | Control Days | Convulsion Days |
| Total | 1438.2 | 2126.4 |
| Mean | 28.8 | 81.8 |
| Difference | | 53.0* |

* Significant at less than 1% level.

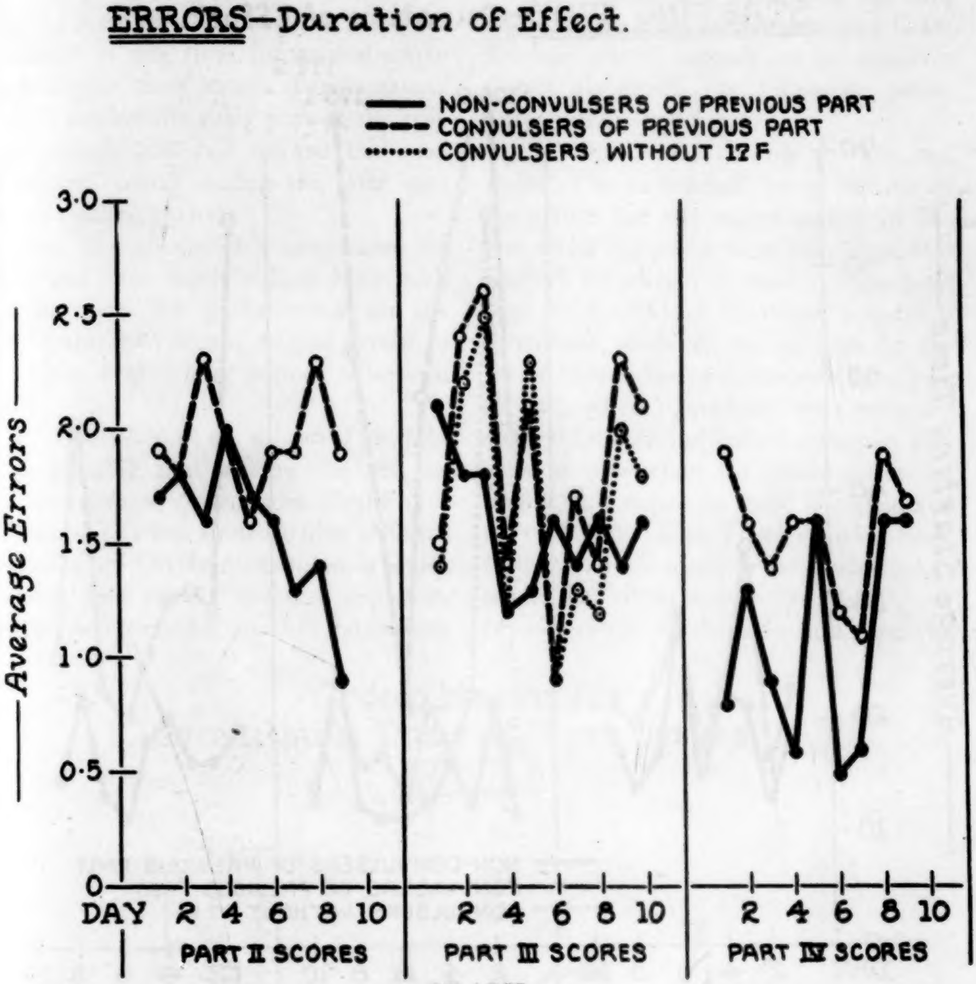
*(b) Relation of convulsions to position habits.* Position habits have already been discussed in relation to their occurrence during the exposure period, and it has been pointed out that of the 18 animals having position habits during the exposure periods, 16 were convulsers and 2 had demonstrated position habits of long standing before the beginning of tests. It, therefore, becomes of particular interest to examine the records of convulsers, especially for convulsion days. This was done by matching days of convulsions with days on which position habits occurred in the individual rats. Certain of the animals showed a striking coincidence between the development of position habits, or revival of position habits previously abandoned, and the occurrence of a convulsion on the same day. The inference gained from this study of the relation between position habits and convulsions is that for certain animals there is a distinct tendency to develop, revert to, or maintain position habits during periods when convulsions are occurring, and in some cases there is a close relationship between the occurrence of a convulsion and the occurrence of a position habit on the same day.

*(c) Relation of convulsions to qualitative disturbance.* In order to study the relationship between frequency of convulsions and frequency of the qualitative disturances described in a preceding section, the last 30 days of the experiment, days 69 to 98 inclusive (the period during which auditory exposures were in progress), were taken as a sample period. The number of "*x*-runs" made by the different individuals were then compared as follows: The mean number of "*x*-runs" per day for convulsers on convulsion days during the sample period in question was compared with the mean number of "*x*-runs" per day for all animals on control days (when the animals were not exposed to sound).

Twenty-seven out of 50 animals showed qualitative changes in behavior on unexposed days, and 17 out of 23 on days convulsions occurred. The average number of "*x*-runs" on the days when convulsions occurred was 3.5 "*x*-runs" per rat per day, while the average number on control days was 0.4 "*x*-runs" per rat per day. (Animals showing the behavior averaged 4.6 "*x*-runs" on convulsion days and 0.8 on control days.) The differences in favor of convulsion days (3.1, 3.8) indicate that there was a clear-cut observable alteration in behavior following the occurrence of a convulsion on the same day.

The total number of "*x*-runs" during the terminal 30-day period was compiled for each animal, and the animals were then divided into two groups. The "convulsers" included all animals which had convulsions at any time during the entire experiment; the "non-convulsers" were animals which at no time had convulsions. The group mean numbers of "*x*-runs" for the two groups were then compared.

Only 6 rats out of the 24 in the nonconvulser group ever showed behavior

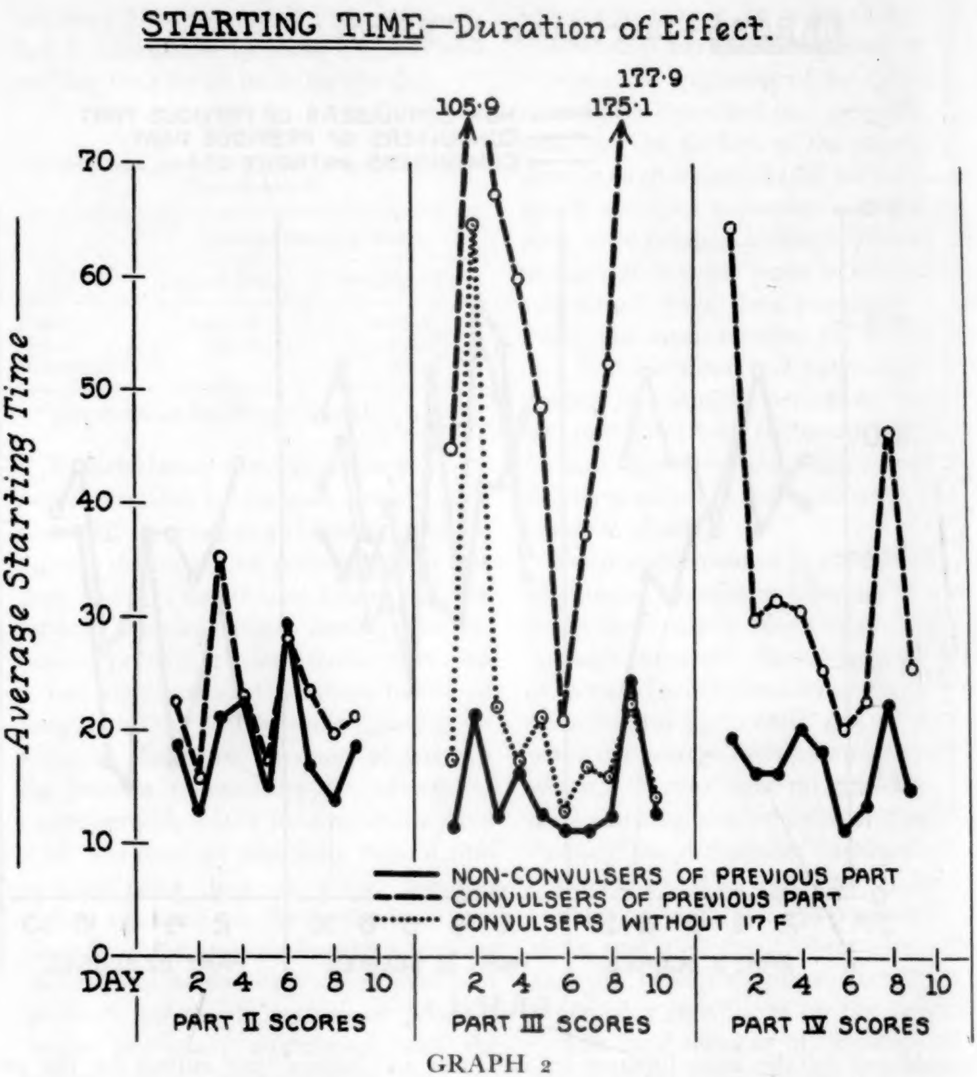



GRAPH 1

considered by the experimenter to indicate disturbance, while 21 out of the 26 animals in the convulser group showed behavior indicating disturbance at some time or other during the sample period.

The average number of "x-runs" for each non-convulser during the 30-day terminal period was 2.6, while the average number of "x-runs" for each convulser during the same period was 31.5. If only individuals which showed the behavior are included, the average number of "x-runs" for the non-convulsing group was 1.1 "x-runs" per animal for the period, while for convulsers the average was 39.0 "x-runs" per animal for the period. The differences clearly show that behavior indicating disturbance occurred with much greater frequency in the convulsers than in the non-convulsers.

*(d) Duration of effect.* To find the duration of the effect of convulsions on error and time scores, the animals were divided into two groups, convulsers vs. non-convulsers after each exposure series, and their scores during the subsequent




GRAPH 2

control period were studied day by day. If a marked effect of the convulsion persists for several days, convulsers should show higher error and time scores than the non-convulsers during the early part of the subsequent control periods, and should approach the scores of the non-convulsers during the later part of the control periods, as the effect wore off.

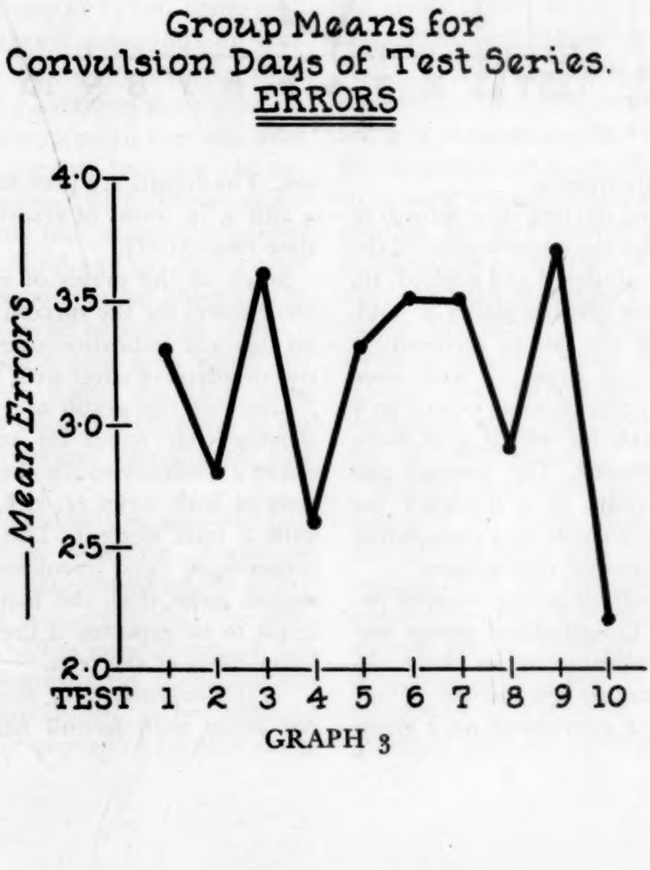
Since the animals were not all tested simultaneously, they were subdivided into groups according to the time of testing. A group mean was obtained for the convulsers and for the non-convulsers for each day of the control period in question. The results are demonstrated in Graphs 1 and 2. The *error curves* (Graph 1) show no tendency at any time for convulsers to have higher error scores than non-convulsers during the early part of the control periods and fall toward the non-convulsers' scores during

the later part of the control periods. The *starting time curves* (Graph 2) show no tendency at any time for convulsers to have higher time scores than non-convulsers during the early part of the control periods and fall toward the non-convulsers' scores during the later part of the control periods.

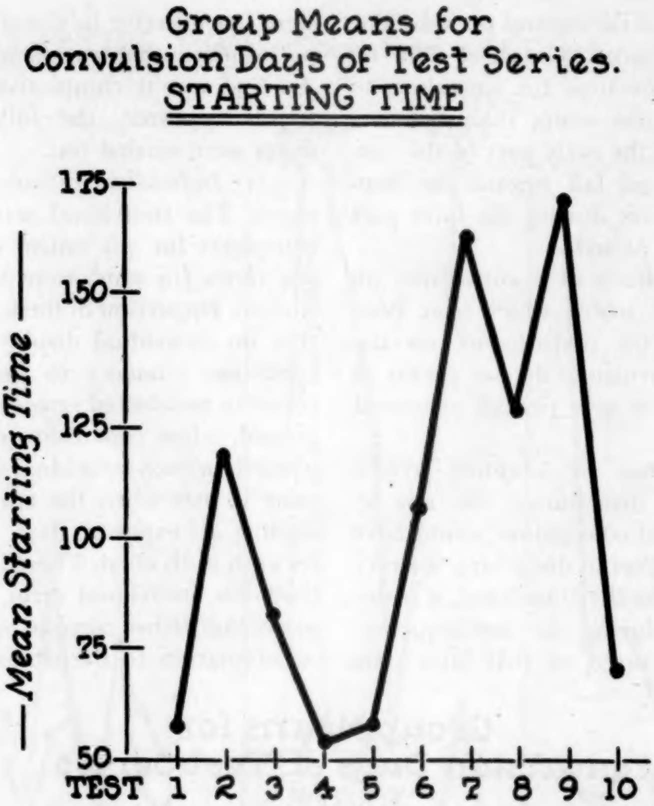
Thus, the effects of a convulsion on error and time scores, which have been demonstrated for performance on the day of the convulsion, do not persist to any great degree over periods of several days.

*(e) Cumulative or adaptive trends.* It is possible that during the test sequence repeated convulsions would have a cumulative effect in disturbing the rat's performance. On the other hand, it is also possible that during the test sequence, adaptation occurred so that later tests were less effective in disturbing the rat's performance than earlier ones had been. To find out if cumulative or adaptive trends appeared, the following procedures were carried out.

(1) *Individual records for the test series.* The individual error records of convulsers for the entire course of the test series (10 tests) were tabulated and studied. Inspection of these records shows that no individual displayed a marked consistent tendency to increase or decrease in number of errors as testing progressed, when convulsion days only are studied for each individual sequence. The same is true when the entire series, including all exposure days, is considered for each individual. There is no evidence from the individual error performance scores that either cumulative disturbance or adaptation to the situation occurred




GRAPH 3




GRAPH 4

during the test sequence.

The individual starting time records of the convulsers for the entire course of the test series were tabulated and studied. Inspection of these records shows a tendency of some of the rats to increasingly prolonged starting times as tests were repeated. It appears to some extent in 7 of the 12 animals for which 3 or more convulsions occurred. The general picture seems to point to a tendency for starting time to increase in a cumulative manner with repeated convulsions.

(2) *Longitudinal group records for the test series.* Longitudinal group records for the exposure series were obtained by averaging the scores of all animals having a convulsion on a given test. The results are presented in Graphs 3 and 4, in terms of errors and starting time respectively.

Study of the graph of group average *error scores* for the successive tests shows no clear-cut indication of either cumulative or adaptive effect with repeated tests.

Study of the graph of group average *starting time scores* for successive tests shows a tendency to rise during the early tests of both series (2, 3, 6, 7, 8, and 9) with a later descent. The rise is more pronounced and prolonged for the second series than the first. This is the result to be expected if there is a cumulative effect of the tests.

(3) *Comparison of first half of the test series with second half.* For those

individuals which had convulsions during both halves of their test series, i.e., during the first five exposures and the second five exposures, it is possible to compare scores for the two series. There were 14 individuals in this category, and individual scores on convulsion days have been prepared for them, divided into averages for the first five tests vs. averages for the second five tests.

Out of the group of 14 rats being considered, 7 averaged *more* errors on convulsion days of the second test series than the first, 6 averaged fewer on the second test, and 1 made the same average error scores for both series. The group mean averages were 3.0 errors for the first half, and 3.2 errors for the second half. There is no indication from these data that either cumulative or adaptive effects occurred.

Out of the group of 14 rats being considered, 11 averaged more time on convulsion days of the second test series than the first, while 3 averaged more time on the first. The group mean averages were 65 seconds for the first half and 123 seconds for the second half. These results tend to confirm the impression gained from the individual and graphic studies that there is a cumulative effect of the convulsions in terms of starting time.

(4) *Position habits.* Rats which developed position habits during a series of convulsions showed a tendency to do so only after several convulsions had occurred.

*(f) Defective learning vs. defective performance.* Since learning continued throughout the experiment for the group as a whole, it is possible that the deleterious effects of the convulsions are due to impaired learning, in those animals which had convulsions, rather than to impaired performance in a familiar situation. In order to study this question, rats which had learned were selected, and their performance on convulsion days was compared with their own performance on control days and also with the performance of non-convulsers on test days.

For convulsers on convulsion days a mean daily error score was obtained by selecting only those animals which had met the learning criterion. Mean daily error scores were also obtained for the control period of the same animals. Group mean scores were calculated for these learners for convulsion days as compared with control days.

The convulsers made a group mean score of 1.8 errors per rat per day on convulsion days, compared with a group mean score of 1.0 errors per rat per day on control days, a difference of 0.8 errors. For the entire group of rats the corresponding means were 2.6 on convulsion days and 1.7 on control days, a difference of 0.9 errors. Thus, the learners showed in terms of absolute number of errors about the same increase as the whole group; and since their absolute number of errors was smaller, learners showed a greater proportional increase in errors on convulsion days than the group as a whole. If anything, the effect of the convulsion in terms of errors is more marked for the learners than for the group as a whole, indicating that the defect is probably one of performance.

Starting time scores analogous to those described for errors were also obtained. The results show that the group mean starting time for convulsers which had learned was, on the convulsion days, 64.7 seconds per rat per day; and on control days, 22.7 seconds per rat per day, a difference of 42.0 seconds. For the entire group of rats the corresponding means

were 81.8 and 28.8, a difference of 53.0 seconds. The learners showed an absolute difference of the same order of magnitude as the entire group, and since the absolute scores for the selected group of learners are slightly lower, the relative increase on convulsion days is greater than for the group as a whole. The inferences are the same as those derived from the error scores.

The daily mean error and starting time scores for the group of convulsers which learned on the days they convulsed, calculated as previously described, was compared with the average of the daily mean error and starting time scores for animals which had learned but did not have convulsions on the test days.

The learner group mean score for convulsers on convulsion days was 1.8, and for the non-convulsers on test days was 0.5 errors, a difference of 1.3 errors. The corresponding scores for the whole group were 2.6 errors for convulsers on convulsion days, and 1.8 errors for non-convulsers on exposure days, a difference of 0.8 errors. The difference for the learners is both absolutely and relatively greater than for the group as a whole, indicating that the defect is probably one of performance rather than learning.

Increase in errors is commonly considered to show impaired learning, while increase in time is commonly considered to show impaired performance due to certain factors, e.g., emotional changes. Throughout the experiment, time proved a more sensitive measure of disturbance, indicating again that the changes in behavior were primarily due to defects of performance.

*(g) Regression.* In discussing position habits in previous connections, it was suggested that this type of response represents an inadequate solution of the animal's problem. Animals which developed position habits did so for the most part early in the course of practice and abandoned them soon afterward for the more adequate goal-oriented response. However, it has also been shown that certain animals demonstrated position habits during the testing period. While this was a new event for certain animals, for other animals it was a return to a habit previously abandoned. If regression implies reversion of the animal to a (relatively inadequate) pattern previously developed and abandoned, rats in the last-mentioned group showed regression.

Position habit records were inspected for regression in the individual animals by selecting those rats which had developed a position habit and abandoned it before day 40 (three weeks before the start of the sound tests), but subsequently demonstrated the habit during the period of exposure to sound. Five rats fulfilled the criteria. It is of considerable interest that all five of these animals were convulsers. The data indicate that regression as here defined may occur in convulsers during periods of exposure to noise.

*(h) Manner of expression of disturbance in individual animals.* It has been seen that convulsions, by various different criteria, produced a disturbance in the performance of many of the animals. It is interesting to examine whether a rat which was disturbed expressed the disturbance in one or two ways only, which provided an adequate outlet; or whether a disturbed animal tended to manifest changes in several of the respects studied, indicating a generalized change in the individual.

Inspection of the data shows that there is a tendency for the same animals to

have extreme scores in the several different categories of disturbance. Only one animal having more than the mean number of convulsions failed to express disturbance following noise stimulation in other respects as well. There is an indication that a disturbed rat finds a variety of expressions for the disturbance.

In order to study the manner of expression of the disturbance further, biserial correlations were obtained for the entire group of animals dichotomized between convulsers and non-convulsers with respect to: *(a)* average errors in all test days; *(b)* average starting time; *(c)* average total time; *(d)* number of *x*-runs. The correlations are given in Table 6.

The correlations are all positive and of moderate degree. They indicate that convulsers showed more errors, longer starting time, longer total time, and more "*x*-runs" than the non-convulsers. This comparison further supports the inference that a disturbed animal expressed the disturbance in a variety of different ways following a sound-induced convulsion.

TABLE 6

INDIVIDUAL EXPRESSION OF DISTURBANCE
BISERIAL CORRELATIONS

| | $N_T$ | *BIS* |
|---|---|---|
| Average Errors (All Test Days) | 50 | (.36) |
| Average Starting Time | 50 | (.51) |
| Average Total Time | 50 | (.51) |
| *X*-Runs | 50 | (.50) |

## III. SUMMARY AND CONCLUSIONS

An experiment has been described in which 50 rats were trained for 61 days in a difficult discrimination situation, following which they were exposed to noise on 10 occasions each. Practice on the discrimination continued during the period of exposure to sound. The relationships between learning and susceptibility to convulsions, and the effects of exposure to sound on performance were analyzed.

1. With respect to the relation between learning ability and susceptibility to convulsions, it was found that there is no evidence that the two are related in any way, either for good learners or for the group as a whole.

2. With respect to the effects of auditory stimulation on discrimination performance, it was found that exposure to sound in itself does not produce changes in behavior by any of the criteria used, but occurrence of a convulsion does lead to increased error and starting time scores, to stereotypy, to regression, and to qualitative changes in behavior. The disturbance could not be detected during subsequent control periods of several days' duration. The defect is one of performance rather than learning, and is expressed by individual rats in a variety of ways, i.e., is generalized in nature.

It is concluded that behavior alterations of rats in a discrimination learning situation which occurred following sound-induced convulsions were characteristic of animals in a disturbed emotional state. The effects are comparable in essential respects to those seen following convulsions obtained by other techniques in rats, and to phenomena seen in man following shock treatment and in epilepsy. The generalized psychological explanation in terms of emotional disturbance cannot be traced directly to the frustrating conditions preceding the convulsion, to the convulsion itself, or to the subsequent catatonia but will probably find its physiological counterpart in some equally general organic disturbance interfering with normal cellular metabolism.

## REFERENCES


1. Maier, N. R. F. *Studies of abnormal behavior in the rat: The neurotic pattern and an analysis of the situation which produces it.* New York: Harper, 1939.
2. Maier, N. R. F. Attention and inattention in rats. *J. genet. Psychol.*, 1930, 38, 288-306.
3. Maier, N. R. F., & Glaser, N. M. Studies of abnormal behavior in the rat. II. A comparison of some convulsion producing situations. *Comp. Psychol. Monogr.*, 1940, 16, 1-30.
4. Lindquist, E. F. *Statistical analysis in educational research.* Boston: Houghton Mifflin, 1940.